United States Patent [19]

Patton et al.

[11] **4,138,683**

[45] **Feb. 6, 1979**

[54] **SHORT RADIATING HORN WITH AN S-SHAPED RADIATING ELEMENT**

[75] Inventors: **Willard T. Patton**, Moorestown; **Norman R. Landry**, Willingboro, both of N.J.

[73] Assignee: **RCA Corporation**, New York, N.Y.

[21] Appl. No.: **817,687**

[22] Filed: **Jul. 21, 1977**

[51] **Int. Cl.**[2] **H01Q 3/26**

[52] **U.S. Cl.** **343/783**; 343/772

[58] **Field of Search** 343/786, 783, 772–774

[56] **References Cited**

U.S. PATENT DOCUMENTS

3,534,376	10/1970	Webb	343/786
3,778,717	12/1973	Okoshi et al.	343/772

Primary Examiner—Alfred E. Smith

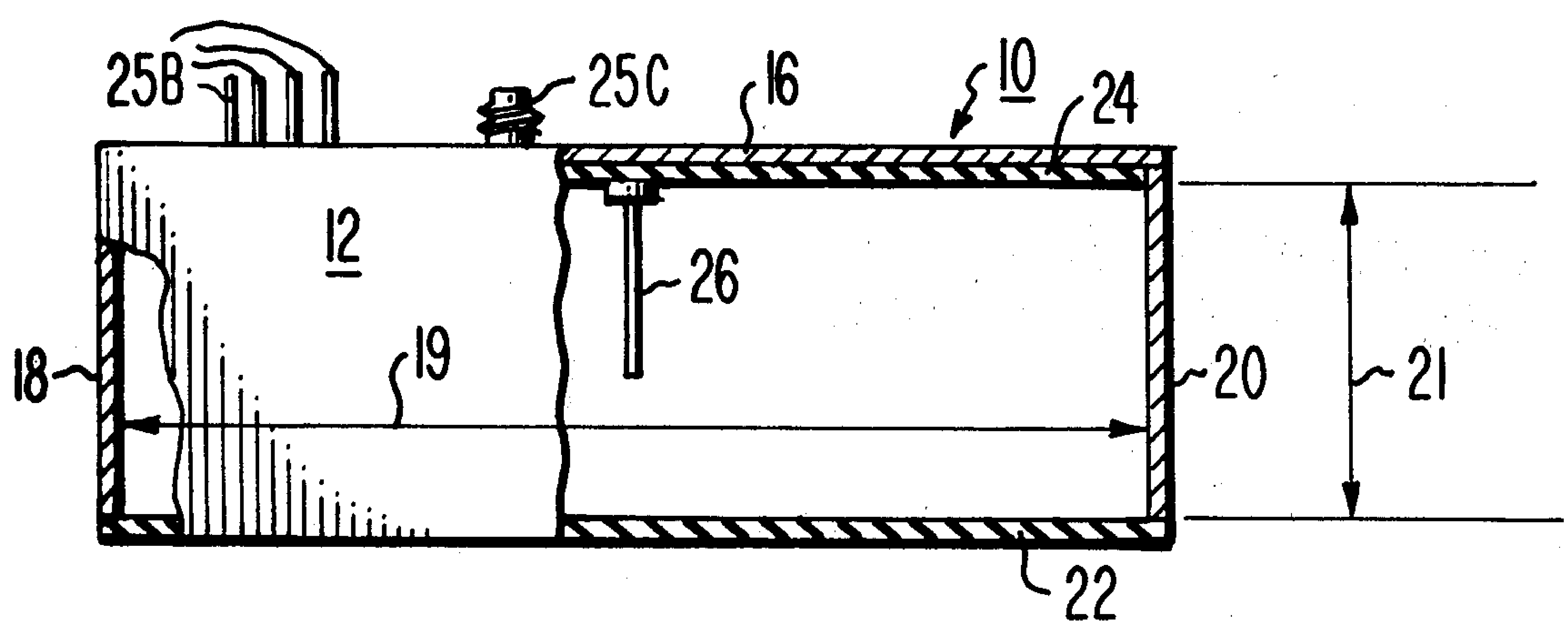
Assistant Examiner—David K. Moore

Attorney, Agent, or Firm—H. Christoffersen; Joseph D. Lazar

[57] **ABSTRACT**

The rear wall of a horn antenna is a substrate with a phase shifter circuit thereon. Power from the phase shifter is radiated by the horn via a probe that has the general shape of a hook.

3 Claims, 3 Drawing Figures



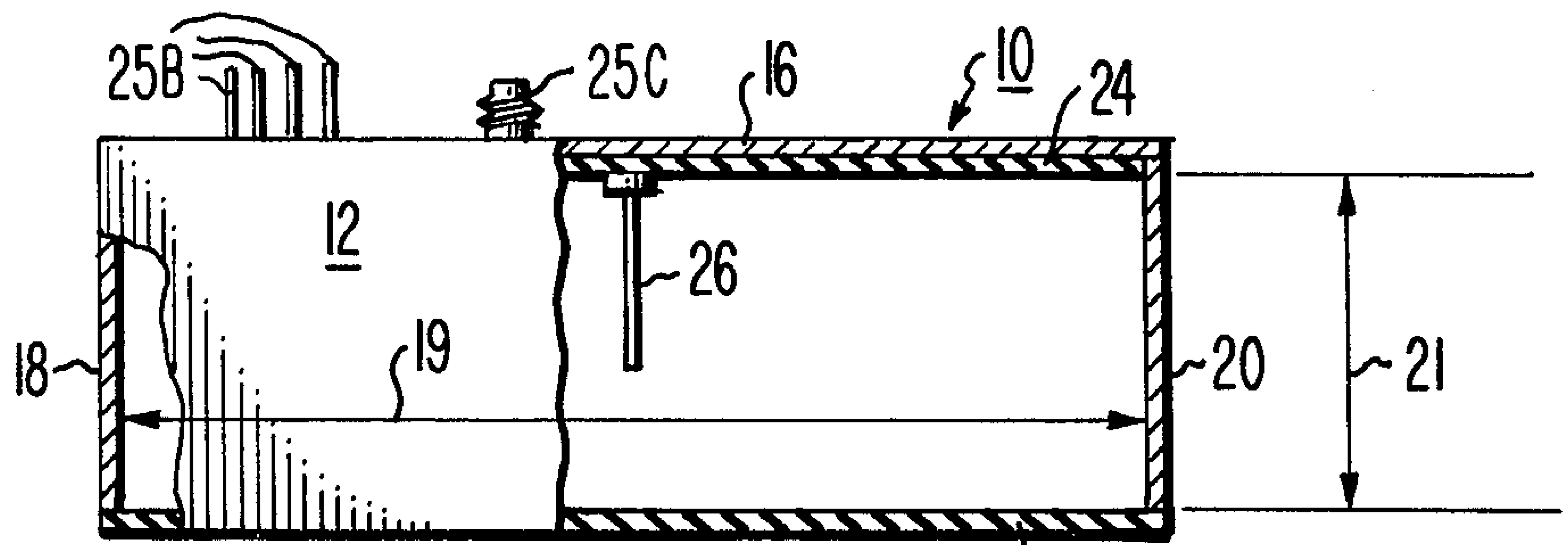


Fig. 1

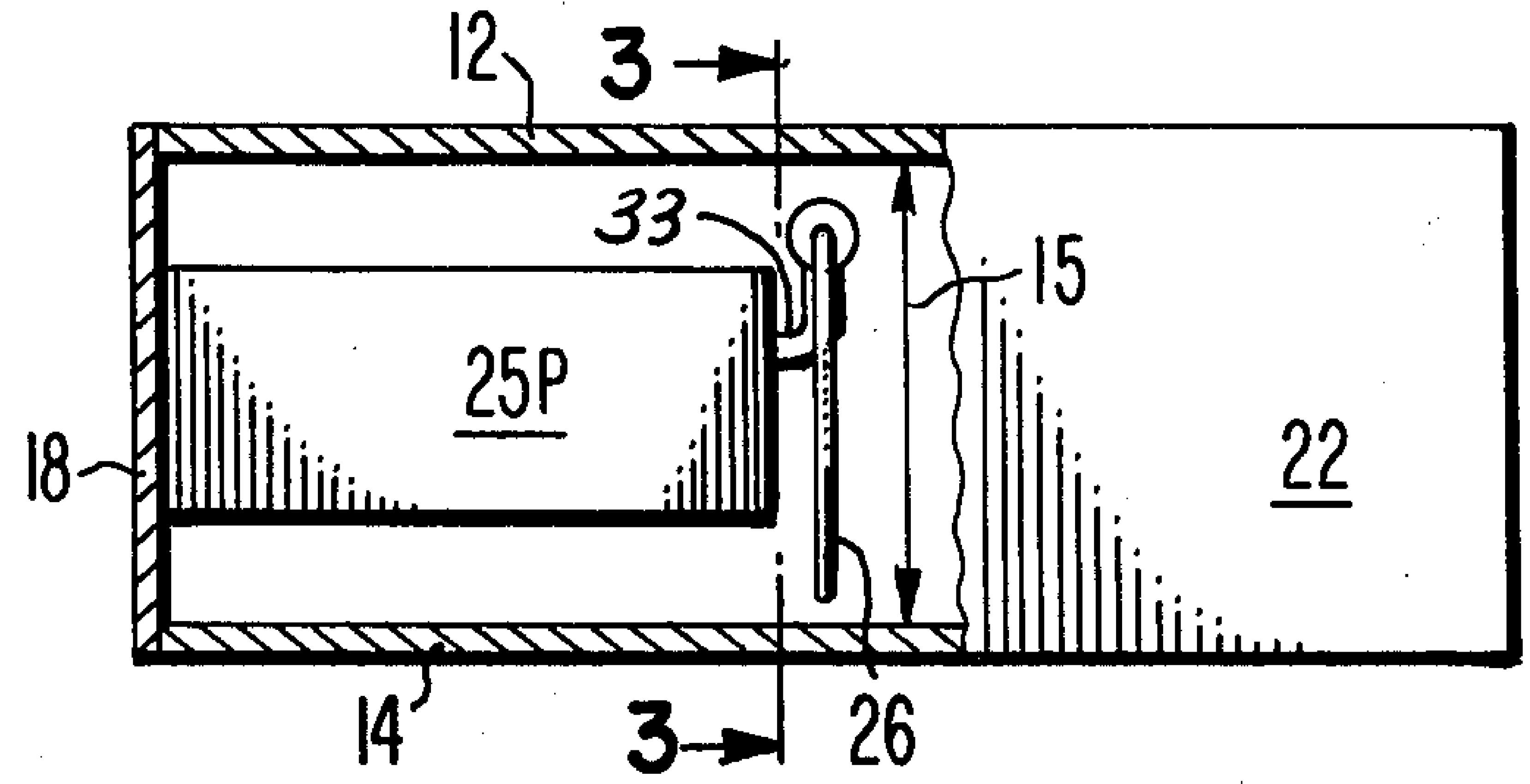


Fig. 2

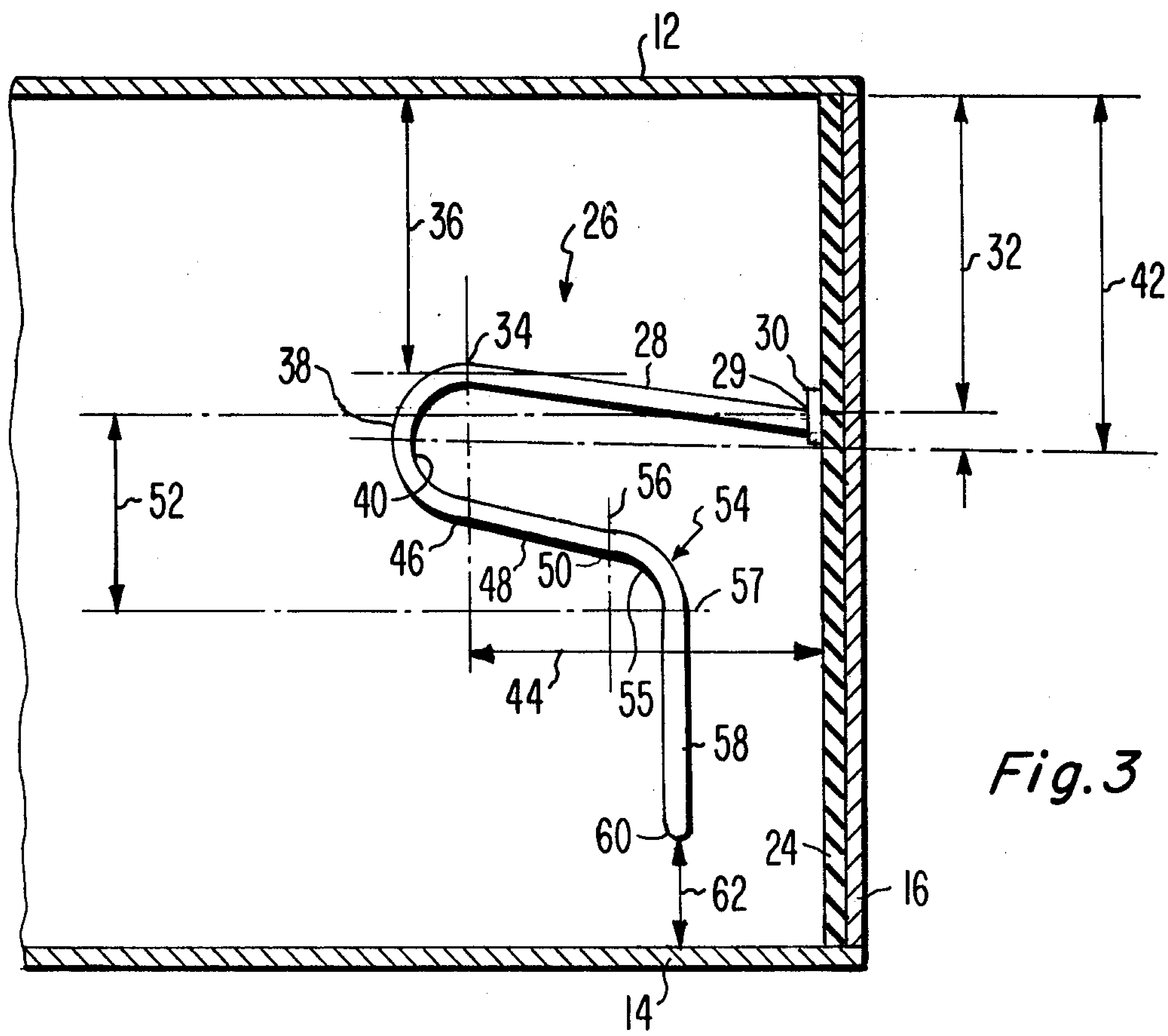


Fig. 3

SHORT RADIATING HORN WITH AN S-SHAPED RADIATING ELEMENT

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to radar and more particularly to phased array radar.

2. Description of the Prior Art

An antenna in one type of a phased array radar is comprised of 4480 radiating horns. Each of the horns provides a three thousand watt pulse of radiation that comprises a component of a radar beam. In the horn, the radiation is in a TE_{10} mode. Outside of the horn, the radiation is in a TEM mode.

The beam has a direction that is usually expressed as a pointing angle subtended from a central axis of the antenna. The pointing angle is determined by the respective phase angles of excitation of the horns. The excitation with desired phase angles is provided to the horns via phase shifters. Since the antenna is comprised of **4480** horns the radar includes 4480 phase shifters.

An undesired coupling of signals from the phase shifters is obviated by enclosing each of the phase shifters in a metal enclosure. Accordingly, the phase shifters and horns comprise 4480 subassemblies where each of the enclosures has a proximal surface that abuts the closed end of the horn.

Electromagnetic energy propogates in a subassembly along a path from a phase shifter to a horn through an interface therebetween. The interface is a discontinuity in the path. Because of the discontinuity, the horn may be excited in modes of orders that are higher than the TE_{10} mode. The excitation in the higher order modes affects the radar beam in an unpredictable manner.

The horn is on the order of twenty centimeters from its closed end to its open end. The twenty centimeter length is needed to provide a region in the horn where there is a decay of the energy in the higher order modes. Moreover, the twenty centimeter length provides for space near the open end of the horn where a pair of capacitive coupling irises and an inductive coupling iris are disposed to provide an impedance match between the horn and free space.

The subassembly typically has a length of thirty two centimeters from the distal non-abutting surface of the enclosure of the phase shifter to the open end of the horn. Since there are **4480** phase shifters and **4480** horns, the phased array radar is bulky and heavy.

The discontinuity is eliminated from the subassembly when the horn and the phase shifter are of an integrated construction. An integrated subassembly has not been constructed because of a belief that an undesired coupling between the horn and the phase shifter is inherent in the integrated subassembly.

SUMMARY OF THE INVENTION

According to the present invention, the exterior of a horn antenna has the general shape of a rectangular parallelepiped that is open on one side. The interior of the horn includes an integrated phase shift circuit disposed upon a substrate that forms a wall of the horn opposite from the open side. A probe comprised of a wire in the general shape of a hook has a section that is connected to the substrate and a section parallel to the substrate. Excitation applied to the phase shifter causes the probe to establish within the horn an electric field with lines of force parallel to the substrate, thereby establishing a TEM mode of propagation of electromagnetic energy from the open side.

BRIEF DESCRIPTION OF THE DRAWING

FIG. **1** is a plan view, with parts broken away, of a preferred embodiment of the present invention;

FIG. **2** is a front view, with parts broken away, of the embodiment of FIG. **1**; and

FIG. **3** is a fragmentary view of the embodiment of FIG. **1** taken along the line **3—3** of FIG. **2**.

DESCRIPTION OF THE PREFERRED EMBODIMENT

The preferred embodiment is a horn of a phased array radar antenna that operates in what is known as the S-band (3.1 GHz to 3.5 GHz). However, it should be understood that the invention is applicable to frequency ranges other than the S-band.

As shown in FIGS. **1** and **2**, a horn **10** of a phased array radar antenna has a metal top wall **12** and a metal bottom wall **14** that are separated by a distance **15** which approximately equals 1.969 centimeters. Walls **12** and **14** are connected to a metal rear wall **16** and side walls **18** and **20** to form a rectangular parallelepiped with an open side. In this embodiment, walls **18** and **20** are separated by a distance **19** that approximately equals 7.049 centimeters. Wall **16** and the open side are separated by a distance **21** that approximately equal, 1.918 centimeters.

Preferably, the open side is covered by an alumina wall **22** which is approximately 0.64 millimeters thick. Wall **22** is fixedly connected to top wall **12**, bottom wall **14** and side walls **18** and **20**. Wall **22** protects the interior of horn **10** from rain and snow and dissipates heat when horn **10** radiates a component of a radar beam and, accordingly, may alternatively be formed of a suitable plastic or ceramic insulation other than alumina.

Within horn **10** is an alumina substrate **24** which is approximately 1.27 millimeters thick. Substrate **24** is connected in an abutting relationship with substantially all of wall **16**.

An integrated phase shifter **25P** of any suitable type is disposed upon substrate **24**. Excitation at a frequency in the S band is provided to phase shifter **25P** via a connector **25C** that is mounted on wall **16** and has a center conductor (not shown) that extends through holes (not shown) in wall **16** and substrate **24**.

Preferably, phase shifter **25P** comprised of a plurality of branch line couplers that are loaded by PIN diodes. The PIN diodes are selectively biased to cause phase shifter **25P** to provide a current with a selected phase shift at the S band frequency. Bias signals are provided via a plurality of signal lines **25B** that extend from phase shifter **25P** to the exterior of phase shifter **10** through wall **16** and substrate **24**.

Preferably, phase shifter **25P** is coated with a room temperature vulcanizing silicone rubber, such as that marketed by Dow-Corning Corporation under the trademark, Sylgard. The coating provides electrical insulation of components of phase shifter **25P**. When phase shifter **25P** is coated, it has a 5000 watt power handling capability.

As known to those skilled in the art, alumina has a permittivity greater than the permittivity of air. Therefore, electromagnetic energy that propagates in phase shifter **25P** is concentrated within substrate **24**. The electromagnetic energy with the desired phase shift exits from substrate **24** via a probe **26** that has a disposition and dimensions which have been determined by trial and error.

As shown in FIG. 3, probe **26** is constructed from a cylindrical brass rod with a length of approximately **3.08** centimeters and a diameter of approximately .**965** millimeters. Probe **26** is bent to form the general shape of a hook with a shank that is parallel to substrate **24**. The dimensions of probe **26** are stated hereinafter.

As shown in FIG. 3, probe **26** has a straight exit section **28** with an end **29** connected to the center of a top surface of a gold plated disc shaped brass pad **39** which is described hereinafter. The axis of pad **30** is midway between walls **18** and **20** at a distance **32** from wall **12** which is approximately **0.208** centimeters. Moreover, probe **26** is disposed substantially within a plane midway between walls **18** and **20**.

Pad **30** is connected to phase shifter **25P** by a conductor **33** disposed upon substrate **22**. Phase shifter **25P** provides the current at the S band frequency with the desired phase shift to probe **26**, whereby the electromagnetic energy with the desired phase shift exits from substrate **24** via section **28** and pad **30**. Since probe **26** extends into air, probe **26** radiates the electromagnetic energy.

Section **28** has an end **34** where the center of section **28** is a distance **36** from wall **12**. Distance **36** is approximately 0.170 centimeters. End **34** is integral with an arcuate section **38** that defines an interior line **40**. Line **40** has a center of curvature at a distance **42** from wall **12** and a distance **44** from substrate **24**. Distances **42** and **44** are approximately 0.343 centimeters and **1.011** centimeters, respectively. The radius of curvature of line **40** is approximately 0.125 centimeters.

Arcuate secton **38** has an end **46** that is integral with a straight section **48** that has an end **50**. At end **50**, section **48** is integral with an arcuate section **54** that defines an interior line **55**. Line **55** has a center of curvature at a distance **52** from the axis of pad **30**. Distance **52** is approximately 0.594 centimeters. Additionally, the center of curvature of line **55** is along a line **56** that passes through end **50** and is perpendicular to walls **12** and **14**.

Section **50** has an end **57** that is integral with a straight shank section **58** that is parallel to substrate **24** and has an end **60** that is rounded to have the shape of a hemisphere. Additionally, end **60** is at a distance **62** from wall **14**. Distance **62** is approximately 0.277 centimeters.

Because section **58** is parallel to substrate **24**, excitation applied to phase shifter **25P** causes probe **26** to establish a TEM mode of propagation of electromagnetic energy through wall **22**. Moreover, substantially all energy provided to probe **26** from phase shifter **26P** propagates through wall **22**. It should be appreciated that phase shifter **25P** and probe **26** have a VSWR of less than **1.5**.

Pad **30**, referred to hereinbefore, has a diameter and a thickness of approximately 0.229 centimeters and 0.254 millimeters, respectively.

Since horn **10** has phase shifter **25P** disposed on substrate **24**, horn **10** and phase shifter **25P** are of an integrated construction with no discontinuity therebetween. Because of the integrated construction, a need for coupling irises is obviated whereby distance **21** is typically less than seven percent (i.e., a reduction of 93 percent) of a corresponding distance in a construction where a horn and a phase shifter are not integrated.

What is claimed is:

1. A radiating element of a phased array radar, comprising:

a substantially rectangular alumina substrate;

four metal rectangular walls connected to said substrate to define a parallelepiped with an open side opposite from said substrate;

an integrated phase shifter that provides current in response to an excitation signal and is operable to cause said current to have a selected phase in response to a selection signal, said phase shifter being disposed upon said substrate within said parallelepiped; and

a metal wire probe connected to said phase shifter on said substrate and extending therefrom to the interior of said parallelepiped, said probe having the general shape of a hook with a shank that is parallel to said substrate.

2. The radiating element of claim **1** additionally comprising an alumina wall that covers said open side.

3. The radiating element of claim **1** wherein said probe is substantially within a plane between two of said metal walls that are opposed to each other.

* * * * *